ras reported and Table XI the total number of days on which auroras occurred. The annual sum total given in Table X can be divided by the number, or relative number of stations, which divisors are the same as those for thunderstorms; the quotients or relative frequency of auroras per station are given in the last column of the preceding table.

REDUCTION OF BAROMETER READINGS TO SEA LEVEL.

[Prepared by request, April 4, 1895, by Prof. H. A. HAZEN.]

Table for reducing barometer readings to sea level as used during 1894.

Stations.	Height.	−30°	−20°	−10°	0°	10°	20°	30°	40°	50°	60°	70°	80°	90°
	Feet.													
Abilene, Tex	1,749				2.06	2.01	1.97	1.93	1.90	1.86	1.83	1.80	1.76	1.73
Albany, N. Y	85		.11	.11	.10	.10	.10	.10	.10	.09	.09	.09	.09	.09
Alpena, Mich	609	.78	.77	.75	.73	.72	.70	.69	.68	.66	.65	.64	.63	.62
Amarillo, Tex	3,691	4.38	4.30	4.22	4.14	4.06	3.99	3.92	3.85	3.79	3.72	3.66	3.60	3.55
Atlanta, Ga	1,131				1.34	1.31	1.29	1.26	1.24	1.22	1.19	1.17	1.15	1.13
Atlantic City, N. J	53			.05	.05	.95	.05	.05	.05	.05	.c5	.05	.05	.05
Augusta, Ga	180				.22	.21	.21	.21	.20	.20	.19	.19	.19	.18
Baker City, Oreg	3,430		3.97	3.90	3.83	3.76	3.70	3.64	3.58	3.52	3.46	3.41	3.36	3.31
Baltimore, Md	179			.22	.22	.21	.21	.21	.20	.20	.19	.19	.19	.18
Bismarck, N. Dak	1,681	2.10	2.05	2.01	1.97	1.93	1.89	1.86	1.82	1.79	1.76	1.73	1.70	1.67
Block Island, R. I	27		.03	.03	.03	.03	.03	.03	.03	.03	.03	.03	.03	.03
Boston, Mass	125		.15	.15	.15	.15	.14	.14	.14	.14	.14	.13	.13	.13
Buffalo, N. Y	690	.88	.86	.84	.83	.81	.79	.78	.76	.75	.74	.72	.71	.70
Cairo, Ill	359		.45	.45	.44	.43	.42	.41	.40	.39	.39	.38	.37	.37
Cape Henry, Va	21			.02	.02	.02	.02	.02	.02	.02	.02	.02	.02	.02
Charleston, S. C	52				.06	.06	.06	.06	.05	.05	.05	.05	.05	.05
Charlotte, N. C	773			.94	.92	.90	.89	.87	.85	.83	.82	.80	.79	.78
Chattanooga, Tenn	762			.93	.91	.89	.88	.86	.84	.82	.81	.79	.78	.77
Cheyenne, Wyo	6,105	7.13	6.98	6.83	6.67	6.52	6.37	6.22	6.08	5.95	5.83	5.72	5.62	5.52
Chicago, Ill	824	1.05	1.02	1.00	.98	.96	.94	.92	.91	.89	.87	.86	.84	.83
Cincinnati, Ohio	628		.79	.77	.76	.74	.73	.71	.70	.68	.67	.66	.65	.64
Cleveland, Ohio	740	.95	.93	.91	.89	.87	.85	.83	.82	.80	.79	.77	.76	.75
Columbia, Mo	789	1.01	.99	.97	.95	.93	.91	.89	.87	.86	.84	.82	.81	.80
Columbus, Ohio	824	1.05	1.02	1.00	.98	.96	.94	.92	.91	.89	.87	.86	.84	.83
Concordia, Kans	1,410	1.77	1.73	1.70	1.66	1.63	1.60	1.57	1.54	1.51	1.48	1.45	1.42	1.39
Corpus Christi, Tex	20						.02	.02	.02	.02	.02	.02	.02	.02
Davenport, Iowa	613	.78	.77	.75	.73	.72	.70	.69	.68	.66	.65	.64	.63	.62
Denver, Colo	5,287	6.19	6.07	5.95	5.83	5.71	5.60	5.49	5.38	5.28	5.18	5.08	4.98	4.88
Des Moines, Iowa	869	1.11	1.08	1.05	1.04	1.02	1.00	.98	.96	.94	.92	.91	.89	.88
Detroit, Mich	724	.92	.90	.88	.86	.85	.83	.81	.80	.78	.77	.75	.74	.73
Dodge City, Kans	2,523	3.08	3.02	2.96	2.90	2.85	2.79	2.74	2.69	2.64	2.60	2.55	2.51	2.47
Dubuque, Iowa	651	.83	.81	.80	.78	.76	.75	.73	.72	.71	.69	.68	.67	.66
Duluth, Minn	656	.85	.83	.81	.79	.78	.76	.75	.73	.72	.70	.69	.68	.67
Eastport, Me	76	.10	.10	.10	.10	.10	.09	.09	.09	.09	.09	.08	.08	.08
El Paso, Tex	3,813				4.19	4.11	4.04	3.97	3.90	3.84	3.77	3.71	3.65	
Erie, Pa	714	.91	.89	.87	.85	.83	.82	.80	.79	.77	.76	.74	.73	.72
Eureka, Cal	64				.06	.06	.06	.06	.06	.06	.06	.06	.06	.06
Fort Canby, Wash	179		.22	.22	.21	.21	.21	.20	.20	.20	.19	.19	.19	.18
Fort Smith, Ark	492				.59	.58	.57	.55	.54	.53	.52	.51	.50	.49
Fresno, Cal	338						.39	.38	.38	.37	.36	.36	.35	.35
Galveston, Tex	42						.05	.05	.04	.04	.04	.04	.04	.04
Grand Haven, Mich	628			.77	.75	.74	.72	.71	.70	.68	.67	.66	.65	.64
Green Bay, Wis	617	.80	.78	.76	.74	.73	.71	.70	.69	.67	.66	.65	.64	.63
Harrisburg, Pa	377		.48	.47	.46	.45	.44	.43	.42	.42	.41	.40	.39	.39
Hatteras, N. C	11				.01	.01	.01	.01	.01	.01	.01	.01	.01	.01
Helena, Mont	4,108	4.83	4.74	4.65	4.57	4.49	4.41	4.33	4.26	4.19	4.12	4.05	3.99	3.92
Hannibal, Mo	534	.68	.67	.65	.64	.62	.61	.60	.59	.58	.57	.56	.55	.54
Havre, Mont	2,477	3.03	2.97	2.91	2.86	2.80	2.75	2.70	2.65	2.60	2.56	2.51	2.47	2.43
Huron, S. Dak	1,310	1.65	1.62	1.58	1.55	1.52	1.49	1.46	1.43	1.41	1.38	1.36	1.33	1.31
Idaho Falls, Idaho	4,742	5.49	5.39	5.29	5.20	5.11	5.02	4.93	4.85	4.77	4.69	4.62	4.55	4.48
Independence, Cal	3,950				4.41	4.33	4.25	4.18	4.10	4.03	3.97	3.90	3.84	3.78
Indianapolis, Ind	766	.98	.96	.94	.92	.90	.89	.87	.85	.83	.82	.80	.79	.78
Jacksonville, Fla	43						.05	.05	.05	.65	.05	.05	.05	.05
Jupiter, Fla	28						.03	.03	.03	.03	.03	.03	.03	.03
Kansas City, Mo	963		1.19	1.17	1.14	1.12	1.10	1.08	1.06	1.04	1.02	1.00	.98	.96
Keokuk, Iowa	613	.78	.77	.75	.73	.72	.70	.69	.68	.66	.65	.64	.63	.62
Key West, Fla	22								.02	.02	.02	.02	.02	.02
Kittyhawk, N. C	9					.01	.01	.01	.01	.01	.01	.01	.01	.01
Knoxville, Tenn	980		1.22	1.19	1.17	1.14	1.12	1.10	1.08	1.06	1.04	1.02	1.00	.98
La Crosse, Wis	720	.92	.90	.88	.86	.85	.83	.81	.80	.78	.77	.75	.74	.73
Lander, Wyo	5,377	6.14	6.03	5.92	5.82	5.72	5.62	5.53	5.44	5.35	5.27	5.19	5.11	5.03
Little Rock, Ark	302	.39	.38	.37	.36	.36	.35	.34	.34	.33	.32	.32	.31	.30
Los Angeles, Cal	330						.38	.37	.37	.36	.35	.35	.34	.34
Louisville, Ky	525	.68	.67	.65	.64	.62	.61	.60	.59	.58	.57	.56	.55	.54
Lynchburg, Va	685				.83	.81	.79	.78	.76	.75	.74	.72	.71	.70
Marquette, Mich	734	.93	.91	.89	.87	.86	.84	.82	.81	.79	.78	.76	.75	.74
Memphis, Tenn	330				.40	.39	.39	.38	.37	.36	.36	.35	.34	.34
Meridian, Miss	358				.44	.43	.42	.41	.40	.39	.39	.38	.37	.37
Miles City, Mont	2,374	2.91	2.85	2.79	2.74	2.68	2.63	2.58	2.54	2.49	2.45	2.41	2.37	2.33
Milwaukee, Wis	673	.86	.84	.82	.80	.79	.77	.76	.74	.73	.71	.70	.69	.68
Mobile, Ala	57				.07	.07	.07	.07	.07	.07	.06	.06	.06	.06
Montgomery, Ala	257				.32	.31	.30	.30	.29	.28	.28	.27	.27	.26
Moorhead, Minn	935	1.20	1.17	1.14	1.12	1.10	1.08	1.06	1.04	1.02	1.00	.98	.96	.95
Nantucket, Mass	14					.01	.01	.01	.01	.01	.01	.01	.01	.01
Nashville, Tenn	545		.69	.68	.66	.65	.64	.62	.61	.60	.59	.58	.57	.56
New Haven, Conn	107				.13	.13	.12	.12	.12	.12	.11	.11	.11	.11
New London, Conn	45				.05	.05	.05	.05	.05	.05	.05	.05	.05	.05
New Orleans, La	54				.06	.06	.06	.06	.06	.06	.06	.06	.06	.06
New York, N. Y	185				.22	.22	.21	.21	.20	.20	.20	.19	.19	.19
Norfolk, Va	57				.07	.07	.07	.07	.07	.07	.06	.06	.06	.06
Northfield, Vt	872		1.08	1.06	1.04	1.02	1.00	.98	.96	.94	.92	.91	.89	.88
North Platte, Nebr	2,841	3.45	3.38	3.31	3.25	3.19	3.13	3.07	3.01	2.96	2.91	2.86	2.81	2.76
Oklahoma, Okla	1,239			1.50	1.47	1.44	1.41	1.38	1.36	1.33	1.31	1.28	1.26	1.24
Omaha, Nebr	1,123	1.42	1.39	1.36	1.33	1.30	1.28	1.25	1.23	1.21	1.18	1.16	1.14	1.12
Oswego, N. Y	335	.44	.43	.42	.41	.40	.39	.39	.38	.37	.36	.36	.35	.35
Palestine, Tex	510					.60	.59	.58	.57	.56	.55	.54	.53	.52
Parkersburg, W. Va	638	.82	.80	.78	.77	.75	.74	.72	.71	.70	.68	.67	.66	.65
Pensacola, Fla	56					.06	.06	.06	.06	.06	.06	.06	.06	.06
Philadelphia, Pa	117					.13	.13	.13	.13	.13	.12	.12	.12	.12
Pierre, S. Dak	1,470	1.84	1.81	1.77	1.73	1.70	1.66	1.63	1.60	1.57	1.54	1.52	1.49	1.46
Pittsburg, Pa	842			1.02	1.00	.98	.96	.94	.93	.91	.89	.88	.86	.85
Port Angeles, Wash	29							.03	.03	.03	.03	.03	.03	.03
Port Huron, Mich	639	.82	.80	.78	.77	.75	.74	.72	.71	.70	.68	.67	.66	.65
Portland, Me	103				.11	.11	.11	.11	.11	.10	.10	.10	.10	.10
Portland, Oreg	157				.19	.19	.19	.18	.18	.18	.17	.17	.17	.16
Pueblo, Colo	4,734		5.38	5.28	5.19	5.10	5.01	4.92	4.84	4.76	4.69	4.61	4.54	4.47
Raleigh, N. C	388				.47	.46	.45	.44	.43	.43	.42	.41	.40	.40
Rapid City, S. Dak	3,280		3.83	3.76	3.69	3.62	3.56	3.49	3.43	3.37	3.32	3.26	3.21	3.15
Red Bluff, Cal	342					.40	.39	.39	.38	.37	.36	.36	.35	.35
Rochester, N. Y	323	.67	.65	.64	.63	.61	.60	.59	.58	.57	.56	.55	.54	.53
Roseburg, Oreg	523				.63	.61	.60	.59	.58	.57	.56	.55	.54	.53
Sacramento, Cal	71				.08	.08	.08	.08	.08	.08	.08	.07	.07	.07
St. Louis, Mo	571		.72	.70	.69	.67	.66	.64	.63	.62	.61	.60	.59	.58
St. Paul, Minn	850	1.08	1.06	1.04	1.02	1.00	.98	.96	.94	.92	.90	.89	.87	.86
St. Vincent, Minn	804	1.02	1.00	.98	.96	.94	.92	.90	.88	.86	.85	.84	.83	.82
Salt Lake City, Utah	4,345				4.81	4.72	4.64	4.56	4.48	4.41	4.34	4.27	4.20	4.14
San Antonio, Tex	679				.82	.80	.78	.77	.75	.74	.72	.71	.70	.69
San Diego, Cal	93				.10	.10	.10	.10	.10	.10	.10	.10	.10	.10
Sandusky, Ohio	629	.81	.79	.77	.76	.74	.73	.71	.70	.68	.67	.66	.65	.64
San Francisco, Cal	153				.18	.18	.18	.17	.17	.17	.16	.16	.16	.15
San Luis Obispo, Cal	234				.28	.27	.27	.26	.26	.25	.25	.24	.24	.23
Santa Fe, N. Mex	6,998				7.21	7.10	6.99	6.88	6.77	6.67	6.57	6.48	6.40	6.31
Sault Ste. Marie, Mich	642	.82	.80	.78	.77	.75	.74	.72	.71	.70	.68	.67	.66	.65
Savannah, Ga	98					.12	.12	.11	.11	.11	.11	.11	.10	.10
Shreveport, La	249				.30	.30	.29	.28	.28	.27	.27	.26	.26	.25
Sioux City, Iowa	1,165	1.47	1.44	1.41	1.38	1.35	1.32	1.30	1.27	1.25	1.23	1.20	1.18	1.16
Seattle, Wash	119		.15	.15	.15	.14	.14	.14	.13	.13	.13	.13	.12	.12
Spokane, Wash	1,930	2.39	2.34	2.30	2.25	2.21	2.16	2.12	2.08	2.05	2.01	1.98	1.94	1.91
Springfield, Ill	644	.82	.80	.78	.77	.75	.74	.72	.71	.70	.68	.67	.66	.65
Springfield, Mo	1,336	1.69	1.65	1.62	1.58	1.55	1.52	1.49	1.46	1.44	1.41	1.39	1.36	1.33
Tampa, Fla	36						.04	.04	.04	.04	.04	.04	.04	.04
Tatoosh Isl'd, Wash	86				.11	.11	.11	.10	.10	.10	.10	.10	.09	.09
Titusville, Fla	44						.04	.04	.04	.04	.04	.04	.04	.04
Toledo, Ohio	674	.86	.84	.82	.80	.79	.77	.76	.74	.73	.71	.70	.69	.68
Tucson, Ariz	2,390				2.76	2.71	2.66	2.61	2.56	2.51	2.47	2.43	2.39	2.35
Valentine, Nebr	2,613	3.18	3.12	3.06	3.00	2.94	2.89	2.83	2.78	2.73	2.69	2.64	2.60	2.55
Vicksburg, Miss	254				.30	.30	.29	.28	.28	.27	.27	.26	.26	.25
Walla Walla, Wash	1,018			1.26	1.23	1.20	1.17	1.14	1.12	1.10	1.08	1.06	1.03	1.01
Washington, D. C	112					.13	.13	.13	.12	.12	.12	.12	.11	.11
Wichita, Kans	1,366		1.69	1.65	1.62	1.58	1.55	1.52	1.50	1.47	1.44	1.41	1.39	1.36
Williston, N. Dak	1,875	2.32	2.28	2.23	2.18	2.14	2.10	2.06	2.02	1.99	1.95	1.92	1.88	1.85
Wilmington, N. C	78				.10	.10	.09	.09	.09	.09	.09	.08	.08	.08
Winnemucca, Nev	4,340			4.84	4.76	4.68	4.60	4.52	4.44	4.37	4.30	4.24	4.18	4.12
Woods Holl, Mass	22				.02	.02	.02	.02	.02	.02	.02	.02	.02	.02
Yuma, Ariz	141						.16	.15	.15	.15	.15	.14	.14	.14

The accompanying table gives the reduction to sea level at all the stations of the Weather Bureau, and the following explanation of the table is added. The formula which lies at the basis of all theoretical reductions of barometer readings to sea level is that of Laplace. It has been found, however, that in the case of individual observations there are serious errors introduced in the application of the formula, and these are due in part to the fact that the temperature argument—that is, the mean of the temperatures observed at the base and summit of an isolated peak—is not the true temperature of the air column. In order to determine an exact reduction for an individual station it is only necessary to arrange each difference in pressure between the summit and base according to the mean temperature between base and summit at the same time. In this way a table has been formed for the reduction of observations at Mount Washington. (See Professional Paper No. VI, p. 8.) The error of the theoretical reductions at 0°, at 22.5 inches, is —0.36 inch, and at 22.0 inches it is —0.23 inch.

If all the high stations in the country were situated like Mount Washington, with a station at sea level, or near the base, it would be an easy matter to determine a table of reduction for each station. In the western portion of the country, however, the high stations are on an elevated plateau, and the above plan must be modified. We may say, in general, that any system which will enable us to draw isobars connecting the reduced values at elevated stations with those quite near sea level and west of the plateau region, may be considered fairly satisfactory as a first approximation. In the practical working out of this principle the plan adopted at Mount Washington was carried out. An approximate law of reduction on the east and west sides of the plateau region was found, and when those were seen to be nearly the same they were united in a single formula which enabled the construction of the table here given. After applying this table to make actual reductions it was found that a few stations, owing to their greater or less isolation or to individual peculiarities, did not have perfectly satisfactory reductions. In those cases it was necessary to modify the temperature argument slightly to bring them in harmony with the rest. These stations at the present time are Baker City, Cheyenne, Denver, El Paso, Santa Fe, and Winnemucca.

It was found that in using the observed temperature for the reduction too much weight was given to existing conditions, as the atmosphere did not seem to respond immediately to temperature changes. By taking a mean of the observed temperature and that at the previous observation a fairly satisfactory result could be had, and this is the adopted method. It has been found that at times there are abnormal conditions of both temperature and pressure which throw out the reduction at a limited number of stations, but even in those cases the general reduction is satisfactory. Such conditions are more prevalent in Wyoming, Idaho, Montana, and in Canada to the north of the latter State.

THE TOTAL QUANTITY OF AQUEOUS VAPOR IN THE ATMOSPHERE.

By Prof. C. ABBE.

The diminution of aqueous vapor in the atmosphere with altitude above sea level was approximately determined by Hann in 1874 (see the collection of translations entitled "Short Memoirs on Meteorological Subjects," Annual Report, Smithsonian Institution, 1877, p. 376). Hann showed that all observations on mountains or in balloons, then available to him, agree in giving a simple law of diminution of vapor tension that is empirical, but not contrary to what we know of the laws of the diffusion of vapor. This law is

$$\frac{p}{p_0} = 10^{\frac{-h}{6517}}$$

where p and p_0 are the vapor tensions at top and bottom of an air column whose height in meters is h. The constant 6517 may vary with the temperature of the column, but observations were not available for determining this fact; Hann subsequently used 6500 as the constant instead of 6517, and this formula agrees within 1 per cent with the general average of all available European observations.

The total quantity of water present as vapor in a unit volume of air at any height in the atmosphere is given by introducing the above equation into the ordinary expression for the weight in kilograms of the vapor in a cubic meter of air, which therefore becomes

$$q = \frac{0.0010582}{1+at} p_0 \; 10^{\frac{-h}{6517}}$$

where a is the coefficient of expansion, and t the temperature of the air in centigrade degrees.

This value for q may be introduced into the differential equation for the quantity of vapor in a column of air reaching from sea level up to the altitude h; the average temperature of the whole column t' is assumed to be the average of the temperatures t_0 at the bottom and t_h at the top of the column. The weight of vapor in kilograms in the whole column of 1 square meter section is expressed by—

$$Q = \frac{0.0010582}{1+at'} p_0 \, 2830\left(1-10^{\frac{-h}{6517}}\right)$$

Tables in English measures based on the above formulæ were prepared in 1884 for an unpublished fourth edition of the Signal Office circular "How to Use Weather Maps," and were also given in a condensed form on pages 409 and 410 of the Smithsonian Report for 1888; in response to several inquiries they are now reproduced herewith (see Table 1 for q and Table 2 for Q).

TABLE 1.—*Normal distribution of aqueous vapor for various altitudes above the earth's surface.*

Altitude in feet above sea level.	Relative tensions or weights by Hann's formula.	Actual weight in grains per cubic foot at any elevation for a given dew-point at the surface.			
		80°.	70°.	60°.	50°.
		Grains.	*Grains.*	*Grains.*	*Grains.*
0	1.000	10.95	7.99	5.76	4.09
2,000	0.806	8.83	6.44	4.64	3.30
4,000	0.650	7.11	5.19	3.74	2.66
6,000	0.524	5.75	4.19	3.02	2.14
8,000	0.423	4.63	3.38	2.44	1.73
10,000	0.341	3.73	2.72	1.96	1.39
12,000	0.275	3.01	2.20	1.58	1.12
14,000	0.221	2.42	1.77	1.27	0.90
16,000	0.179	1.96	1.43	1.03	0.73
18,000	0.144	1.58	1.15	0.83	0.59
20,000	0.116	1.27	0.93	0.67	0.47
22,000	0.094	1.03	0.75	0.54	0.38
24,000	0.075	0.82	0.62	0.43	0.31
26,000	0.061	0.67	0.49	0.35	0.25
28,000	0.049	0.54	0.39	0.28	0.20
30,000	0.040	0.43	0.32	0.23	0.16

The total quantity of vapor in the atmosphere may also be expressed by the depth it would occupy if all precipitated as rain, as in the following paragraphs (for précision the equivalent water is supposed to have the temperature of 39.2°, which is that of the standard maximum density of water):

For a vertical column of 1 square meter section, Q expressed in kilograms is equivalent to Q millimeters of rainfall at 39.2° for that same horizontal square meter.

For a vertical column of one square foot section, Q expressed in grains is equivalent to $\frac{Q}{36415.54}$ inches of rainfall at 39.2° for that same square foot.